26 Apr 1972

System Design and Low-Cost Building Systems in Developing Countries

E. H. Mikho

J. Delrue

SYSTEM DESIGN AND LOW-COST BUILDING SYSTEMS IN DEVELOPING COUNTRIES

by

Dr. Ir. E. H. Mikho,* Dr. Ir. J. Delrue**

SCOPE

The housing problem is one of the most difficult that the governments of developing countries have to solve. It can be solved only by means of "large-scale" programmes capable of dealing with manifold problems which exist, and which aim at finding solutions for the benefit, not only of the few but of the great masses of population who are living in deplorable conditions.

The great and main cause of the housing problems created today in developing countries is the great change in demand for housing facilities in general. (1) This is the result of two important factors: the increase and movement of population with its splitting of patriarchal families and the rise in income. New health conditions, allowing a greater increase of the population than before, have not been followed by an increase of production capacity of the people, who produce perhaps the same number of houses of the same quality as before, while the needs are much greater.

Even if we consider the country's population "stable" being in the era of vast development, the change in its geographical distribution is such that new great needs for houses have been created in all urban and industrial centres of administration. The change in social standards, is another important factor in addition to these two basic problems, and of great influence on house design concept. Thus we infer that these countries need much greater numbers of houses in the urban centres for low-income population as well as for people requiring a higher standard of living.

RESEARCH

We need only to remind you that a great deal of research is needed in order to tackle the housing problem in developing countries. Because it is not enough to ascertain that the problems exist, that so many families are without shelter or badly housed. The problem is so great that even to draw up plans for houses which are to be built is not enough. The problems that affect directly the house design and provision are indeed many. The type of house construction, building materials, climatic conditions, topographical variations, the way of living and thinking, family income, cultural environment, social structure, ethnic groups, etc. all vary from one country to another, even they may vary from one region to another within the same country. Therefore the result of the research in one country may not hold good for another, and applied research in local conditions for each country is essential.

SYSTEM APPROACH

We have been involved recently in a research study on "housing problems in developing countries" (2) and the application of "System Design to low-cost Building Systems" in these countries, with special reference to Iraq. We should like to give a short brief of the design method and the two building systems we developed within this framework.

We have observed that the "large-scale governmental programmes" mentioned before, can only be carried out satisfactorily on a fundamental basis of Building Systems applicable on a national and/or regional base. This is because:

1. Individualism that exists in the house designs, in practice today, is no more capable of dealing with the problem of housing masses of people, and a more comprehensive "System Approach" is essential.
2. "System Approach" is not confined or specific to any one housing problem.
3. Systems require major commitments which merit sound research and development base.

The success of "System Approach" does depend however on a certain number of premises, realizing from the start that the design of a building system is so different from that of an individual house that the usual house design routines are not applicable. Furthermore, a failure to recognize this can lead to some frustrating - and costly - development experiences. (3)

The first premise is the establishment at the project stage of the independence of STRUKTUUR and INBOUW. STRUKTUUR includes everything pertaining to the building and which is likely to combine a long functional life with a long technical life (the "permanent" part of the Building).

INBOUW includes all the parts of the building which must be capable of rapid adaptation to a change in the use of the building which may happen in a very short time (the "adaptable" parts of the building). The essential difference, therefore, between STRUKTUUR and INBOUW is a difference in the anticipated length of life of the different parts of the building.

The second group of premises are concerned with the interrelated "Functional Levels" structured according to a fixed hierarchy which can always be reduced to a typical tree structure. This tree structure can generally be found in each building programme, where each level corresponds to a different level of design decisions.

We should like to consider in more detail the concept of "Functional Levels", and describe a technique of recording requirements. A terminology (4) has been worked out in order to improve communications between all those who are concerned with the project: e.g. architects, engineers, contractors, etc. The complete building programme constitutes the whole "Activity System". It can be analyzed into hierarchical functional levels (fig. 1).

- ACTIVITY UNIT	e. g. Taking Bath
- ACTIVITY SET	e. g. Sleeping Room
- ACTIVITY SECTION	e. g. 4-persons House Unit
- ACTIVITY SYSTEM	
- ACTIVITY SUB-SYSTEM	e. g. Housing Group
- ACTIVITY SYSTEM	e. g. Housing Block or Complex
- ACTIVITY MACRO SYSTEM	e. g. Housing Estate

Sometimes the housing complex (Activity System) is only part of a larger whole, as a housing estate. This constitutes the Activity Macro-System.

Activity Unit: is an ergonomical basic activity, which can be identified by the functional brief, e.g:

Washing Hands
Taking Bath
Sleeping/Single

Any programme of requirements is subdivided into a certain number of Activity Units which are the basic information for the designer. Design information is obtained on each of these Activity Units in the form of Activity Data Sheets. Usually this is of two kinds:

- Information concerning the space and the components of equipment required, based upon anthropometrics.
- Environmental information, concerning both physical and psychological requirements.

Activity Set: is a set of interconnected Activity Units, with at least a mutual compatibility, which can stand or go together in the same environmental climate, and stimulate each other. The set of the following Activity Units constitutes an Activity Set:

2 X single bed area
2 X sitting / easy chair
2 X reading / upright chair.

It is possible to obtain a standard Activity Set Data Sheet as soon as available policies are agreed. Mostly an Activity Set

*B.Sc. Baghdad; Iraq
**University of Leuven, Department of Architecture - Belgium

refers to a well-defined space or room. The Activity Set can be translated into a "Room Data Sheet", provided that agreement is reached on a modular system and other design criteria. But one should remark that this is already a design activity.

Activity Section: is a set of Activity Sets, constituting a recognizable functional whole, from which it is expected that it will evolve homogeneously, e.g.

Living Area; Dining Area; Preparing Food Area;
Bath; W.C.; 2 Double Sleeping Area

constitute one Activity Section (4-persons house unit).

On this technique of recording requirements, a "Data Bank" can be set up on a national or regional basis which will provide those who are concerned with a clear and comprehensive statement of user requirements. Furthermore, this Data Bank as a "design document" can be adapted to respond to the change in the programmes of requirements, which result from:

1. Activity Units which become out-of-date, which are dropped, which disappear and which evolve.
2. Change in the pattern of relationship, the basis of the organization, as a result of regrouping, additions, out cuts etc. Modular Co-ordination is another important problem which has been considered very thoroughly over the whole stage of the design.

SYSTEM BUILDING

We will try to give a short summary of the two "Low-cost Building Systems" (2) built up systematically and developed within the framework of the above-mentioned premises, namely:

1. Independence of the STRUKTUUR and INBOUW (the "permanent" and "adaptable" parts of the building).
2. Functional Levels.
3. Modular Co-ordination.

In developing countries the most, or rather, the only common method of recording requirements is directly a schedule of accommodation with maybe a list of furniture and equipment for each room. But we realized that at this stage of the project the designer needs a great deal more than a schedule of rooms, and the most difficult task is to provide him (the designer) with a clear statement of the requirements. Before he can design successfully, he needs design information about all the activities to be carried out in the various spaces in the house and how these are interrelated.

Simply this was achieved by translating the "Activity Units" (Level 1, Figure 1) into standard "Activity Data Sheets". The "Activity Data Sheet" records the activities and gives the required information before the schedule of accommodation which may presuppose a design solution.

The second step is to translate these activities to space requirements. The minimum required number of activities to constitute an "Activity Set" (Level 2, Figure 1) are grouped to obtain minimum Functional Area. Number, type and the way these activities are arranged give the actual dimensions for the Functional Area. Different dimensions can be worked out with various grouping, depending on the designer capabilities, to manipulate these activities. An important point we should mention here, is that the dimensions worked out should correspond to the foreseeable change in the future pattern of activities.

We are on a level where the "Activity Sets" can be translated again into generic house designs (Level 3, Figure 1) which can be designed with great flexibility on a modular system, in various configurations, depending on the type of house units needed. On this level all the functional units within the framework of the house (rooms, staircase, circulation space) are designed on a modular system in order to coincide with the planning grid adapted 300 mm. Special considerations have been given to the staircases. Modular spaces 900 X 2700 and 1800 X 2100mm are recommended for straight flight and dog-leg stairs respectively. 2600mm is recommended for the floor to floor height.

In this case two-storey compact house plans are designed. The house units are based on a structural grid, 900mm, which coincides with the planning grid 300mm, in order to have the flexibility of upgrading the basic house unit to provide facilities for a larger family by adding more structural grids (Figure 2).

COMPONENT BUILDING SYSTEM

The first building system developed is a COMPONENT BUILDING SYSTEM. The philosophy behind this system is to set up criteria against the whole background of the country and its industrial capabilities. These are:

1. It should be possible to handle manually, by one hand, two hands or two men, all the components in the system.
2. It should be possible to prefabricate all the components on the site by simple moulds without using expensive equipment. But they can be produced mechanically in masses, if required.
3. On the basis of self-help, it should be possible for the dwellers to produce and/or obtain partially or completely all the components.
4. Producing as few numbers of different components as possible in order to reduce construction time and skills required.
5. Considering concrete as a principal structural material for mass production. This is due to expense and difficulties of obtaining other materials, e.g. timber or steel in the required quantities. Concrete in most developing countries appears to

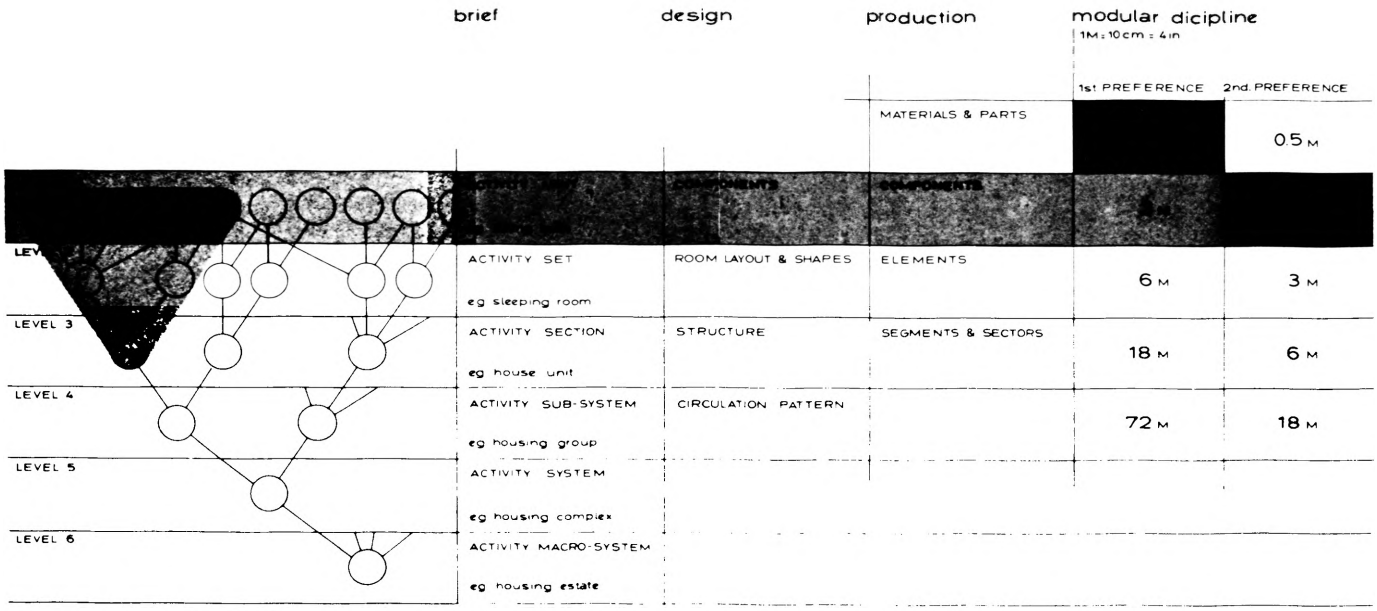


Fig. 1. Typical tree structure Building Programme analyzed into hierarchical Functional Levels, each level corresponding to a different level of design decisions.

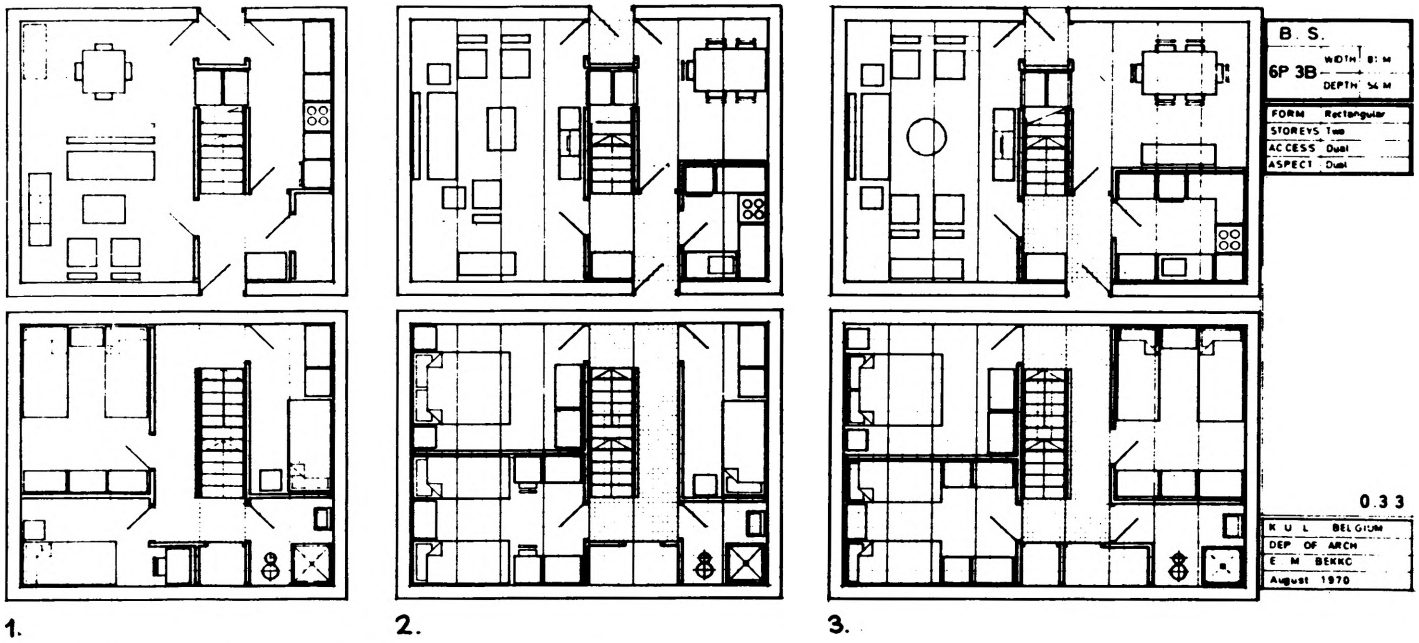


Fig. 2. Two-storey house units, based on structural grid 900mm.
1st plan (7 structural grids) 3 bedrooms, 4 persons
2nd plan (8 structural grids) 3 bedrooms, 5 persons
3rd plan (9 structural grids) 3 bedrooms, 6 persons house unit.

be the best structural material. It has the required characteristics. It can be produced locally, is available almost everywhere and is durable, flexible in use and provides scope for various treatments.

The basic components of the system are:

1. CONCRETE BLOCK
2. FLOOR SYSTEM: JOISTS and FILLER BLOCK
3. STAIRCASE PANELS

1. Three main kinds of prefabricated concrete blocks are designed to meet all the requirements.

Concrete Block A: a hollow block made of no-fines concrete used in bearing walls, of nominal size 600 X 200 X 200mm. Three quarters and half blocks are produced from the basic mould. They are self adjustable (Figure 3).

Concrete Block B: a solid block made of no-fines concrete, used in non-bearing partitions. Nominal block size 600 X 200 X 100mm. Three quarters and half blocks can be produced.

Concrete Block C: a solid block made of dense concrete, used in the outer leaf of the outside wall. A cavity is formed to permit air movement between the inside bearing and the outside non-bearing leaves of the wall. Nominal block size 600 X 200 X 100mm, half block can be produced.

2. The Roof system is very simple and easy to build. It is composed of CONCRETE JOISTS of nominal size 150mm X 150mm and FILLER BLOCKS to span between the joists. The structural grid 900mm coincides with the planning grid 300mm and governs the filler blocksize (Figure 4).
3. Simple moulds are designed to produce STAIR PANELS easily and more than one panel at a time. To be easily handled by two men the stair unit in both dog-leg and straight flight are divided into six X 1500 panels (Figure 5).

A synoptic table is given here to give a clear picture of the system and gives information concerning: dimensions, position, weight, material and sheet references (Figure 6).

SEGMENT BUILDING SYSTEM

Other criteria are considered in designing the second system, SEGMENT BUILDING SYSTEM (5) but on the same principles as the first one. The system is based on industrialized building parts, and mechanical equipment is needed. The system is used where and when this facility is available. The SEGMENT BUILDING SYSTEM is very simply designed and it is composed mainly of two parts: WALL PANELS and ROOF SEGMENTS with of course STAIR PANELS. These are designed to be roughly of the same range of weright in order not to use different mechanical equipment capacity.

The different sizes of the WALL PANELS are precast and produced from only one basic mould with adjustable side forms, which are reduced to a minimum, to give the panel its last shape. The number of the wall panel sizes are reduced to a minimum too. (Figure 7).

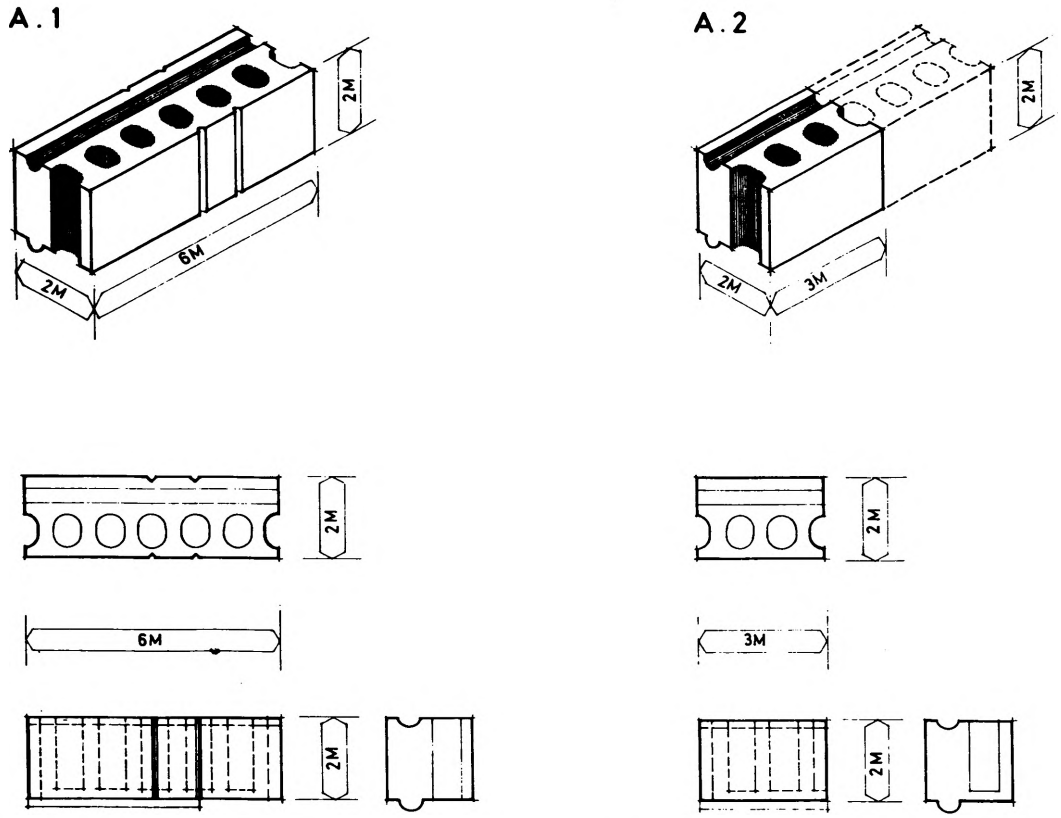
Middle-, end-, and party ROOF SEGMENTS can be produced from one basic roof mould, using side forms to obtain the last form. Roof segments are curve-shaped designed, this is for many reasons, briefly aesthetics, thermal insulation, cross ventilation, etc. The outside ends of the segments can be opened or closed - as the design requires (Figure 8).

In this system the STAIR PANEL is pre-cast as one unit using special moulds to produce more than one at a time.

A synoptic table is given again to give a clear picture of this system and give the required information on dimensions, position, weight, material and sheet reference (Figure 9).

REFERENCES

1. C.A. DOXIADIS, 1961 EKISTICS, pp 264-284; Building Research and Documentation; Elsevier Publishing Company - 1961 London Amsterdam
2. E.H. MIKHO BEKKO, 1970 Low-cost Housing in Iraq, Part 1 Research, Part 2 Housing Building Systems; Mimeographed, University of Leuven
3. EDITORS Developing the Hardware of Building Systems; Industrialization Form, Vol. 1, No. 3, pp 23-28, April 1970
4. Dr. Ir. J. DELRUE, 1969 Architecturale Uitgangspunten voor een Rationalisatie van de Bouwenijverheid; Mimeografie, University of Leuven

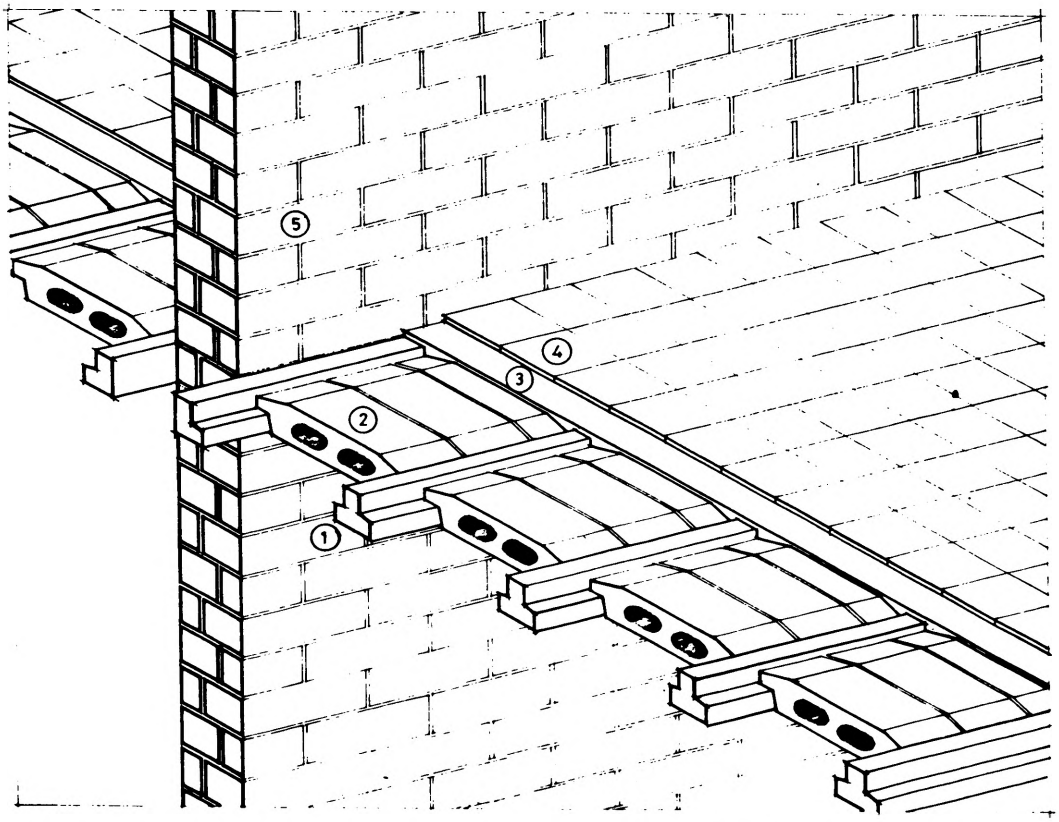


C.B.S.		
CONC. BLOCK NO FINES CONC.		
LENGTH	6 M	3 M
WIDTH	2 M	2 M
THICK.	2M	2 M
WEIGHT	27 kg	13.5 kg

1 1.

K.U.L. BELGIUM
DEPT. OF ARCH.
E.M. BEKKO
August 1970

Fig. 3. Concrete Block A. A hollow block used in bearing walls, three quarters and half block are produced. It is a self adjustable Block (C.B.S.).



C.B.S.	
FLOOR JUNCTION - PARTY WALL	
TYPE	Floor
LOCATION	First floor
CONDITION	
CONT. DIM.	

1 Roof joists. No. 1 3.2
2 Roof blocks. No. 1. 31
3 Cement mortar
4 Tile
5 Party wall

15.7

K.U.L BELGIUM
DEPT. OF ARCH.
E.M. BEKKO
August 1970

Fig. 4. Isometric section showing the roof system. Filler block to span between concrete joists which coincide with 900mm grid.

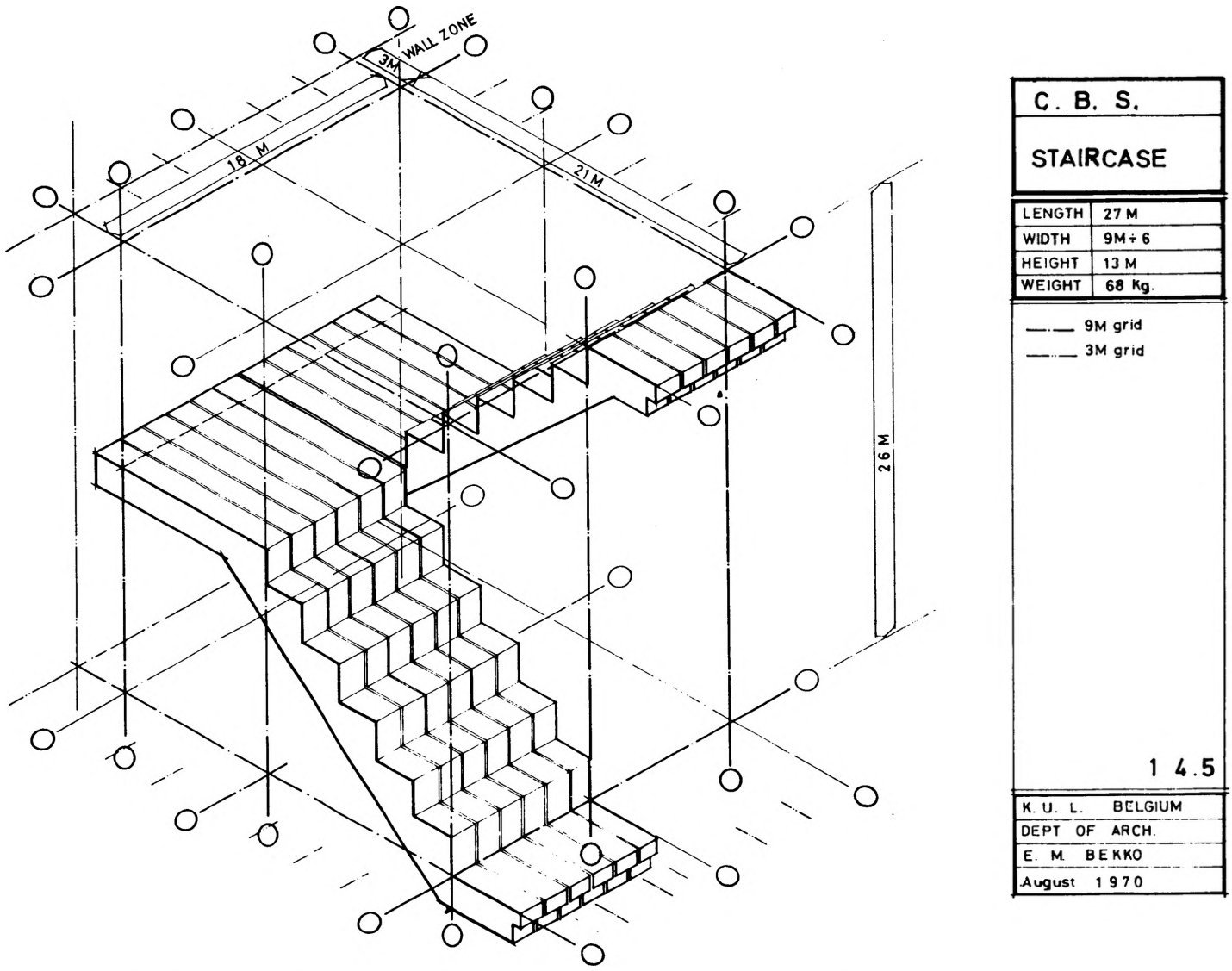


Fig. 5. Dog-leg stair within the modular space 2100 x 1800mm and 2600mm height. The stair unit is divided into six panels each 1500mm (C.B.S.).

SYNOPTIC TABLE

COMPONENT BUILDING SYSTEM

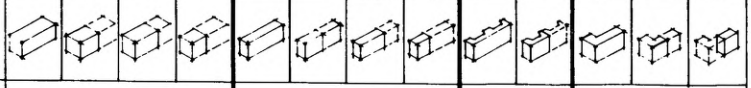
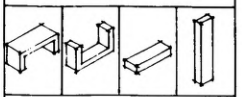
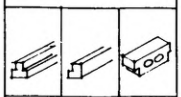
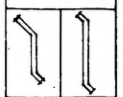
		CONCRETE BLOCKS												WIN.-DOOR F.				ROOF J&B.			STAIR	
INDEX		A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	D1	D2	D3	W.F1	W.F.2	W.F.3	D.F.1	R.F.1	R.F.2	R.B	D.S	S.S.
COMPONENT																							
DIMENSION	LENGTH	6M	3M	4M	2M	6M	3M	4M	2M	6M	3M	4M	2M	2M	12M	12M	12M	17.5M	VARIABLE		8M	21M	27M
	WIDTH	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	4.5M	7.5M	3M	3M	2M	1.5M	3M	H 2.6M	27M
	THICK.	2M	2M	2M	2M	1M	1M	1M	1M	1M	1M	2M	2M	1M	5M	3M	1.5M	1.5M	2M	2M	2M	1.5M	1.5M
MATERIAL	DENSE CONC.									■	■	■	■	■	■	■	■	■	■	■		■	■
	NO.FINES CONC.	■	■	■	■	■	■	■	■												■		
WEIGHT KG.		27	13.5	18	9	18	9	12	6	17	8.5	20	12	8	108	144	75	105	330Max	240Max	47	68	173Max
CARRYING	ONE HAND				■		■		■		■			■									
	TWO HAN.	■	■	■		■		■		■		■	■										
	TWO MEN														■	■	■	■	■	■	■	■	■
CAST IN	FACTORY	■	■	■	■	■	■	■	■	■	■								■	■	■	■	■
	SITE											■	■	■	■	■	■	■					
SHEET No.		1.1.1	1.1.1	1.1.2	1.1.2	1.1.3	1.1.3	1.1.4	1.1.4	1.1.5	1.1.5	1.1.6	1.1.6	1.1.6	1.6.1	1.6.1	1.6.1	1.6.1	1.3.2	1.3.2	1.3.1	1.4.5	1.4.1

Fig. 6. Synoptic table of Component Building System giving a clear picture of the system.

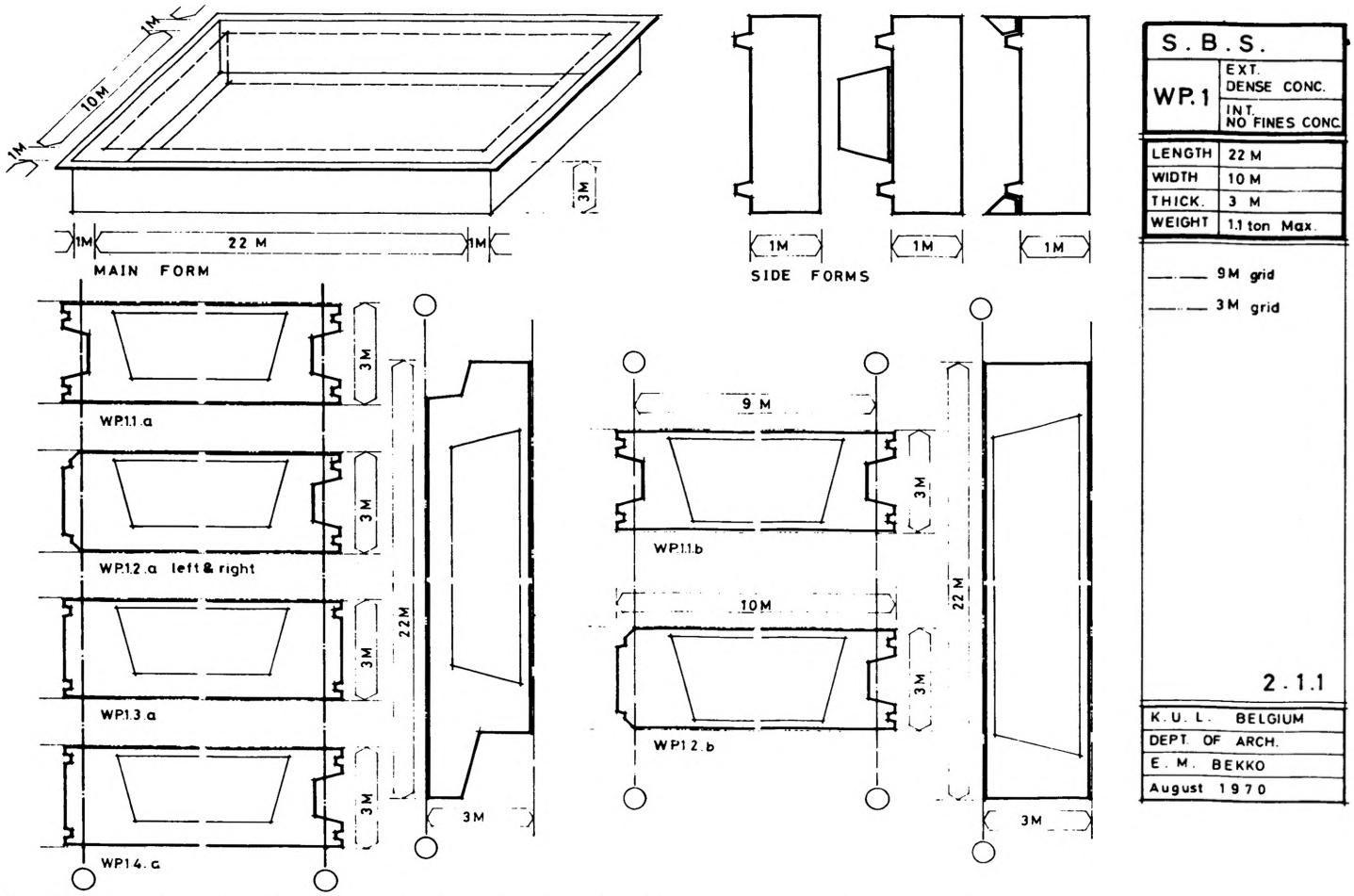


Fig. 7. Wall panels, pre-cast and produced from only the one basic mould using adjustable side form to give the panel the last shape (S.B.S.).

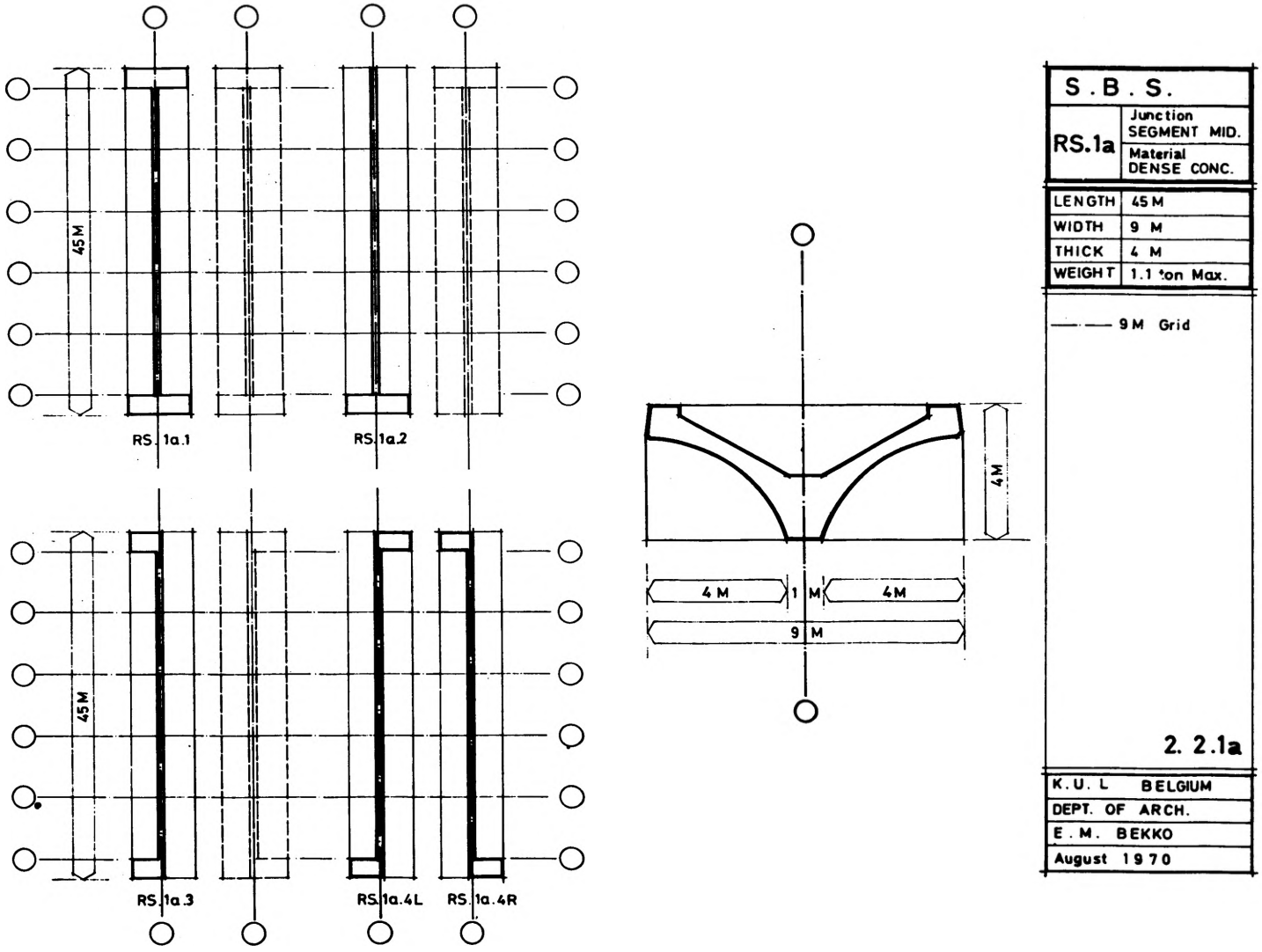


Fig. 8. Roof segments, pre-cast and produced from basic mould with adjustable end forms (S.B.S.).

SYNOPTIC TABLE

SEGMENT BUILDING SYSTEM

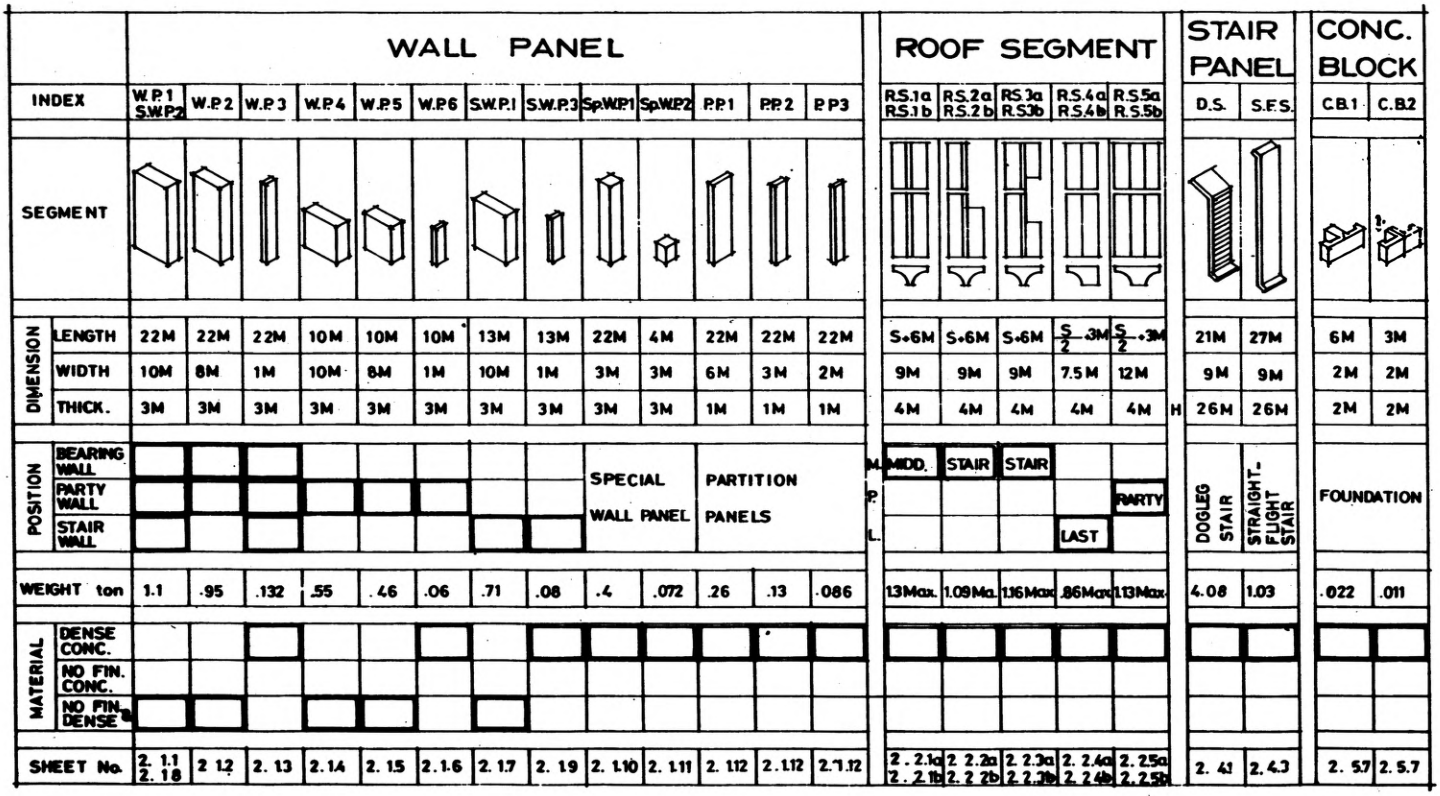


Fig. 9. Synoptic table of Segment Building System giving a clear picture of the system.